Renewable and Sustainable Energy Reviews 16 (2012) 4071–4077

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Thermal comfort in hospitals – A literature review

Jamal Khodakarami*, Nazanin Nasrollahi

Engineering Faculty, Ilam University, Pajohesh Boulevard, Post Box: 69315-516, Ilam, Iran

ARTICLE INFO

Article history:
Received 25 December 2011
Accepted 17 March 2012
Available online 28 April 2012

Keywords:
Thermal comfort
Thermal sensation
Patient
Hospital staff
Iranian hospitals

ABSTRACT

In general, there is a wide range of literature covering the area of thermal comfort, but not a focused literature review of thermal comfort in hospitals has published yet. However, there has been no study on the direct effect of thermal comfort on health. The authors have found a reasonable amount of literature in thermal comfort in hospitals. This paper presents a literature review on thermal comfort in hospitals. From the review, the paper concludes that it is important to undertake original studies in the relationship between thermal comfort conditions and productivity for hospital staff. The study finally concluded that it is important to find some solutions to reconcile the different thermal comfort conditions required by different occupants in hospitals. These solutions could be used whenever patients and the attending caregivers have to stay in one room for a long time compulsorily.

Contents

1. Introduction 4071
2. Literatures of thermal comfort in hospitals 4071
3. Discussion 4075
4. Conclusion and recommendations 4076
References 4076

1. Introduction

Several studies that have led establishing several standards in thermal comfort for occupants in buildings are related to normal groups of occupants in general. Some researches have been undertaking the discussions of the desired thermal conditions for special groups of people, but these studies are not reflected in the forms of standards yet and it looks to be a lack of knowledge in this field. Part of these researches has been done in thermal comfort for hospital occupants, including patients and hospital personnel. The indoor air quality in these environments is still under the shadow of the influence of infections on the healing process of patients. Hygiene and safety are the main parameters to establish building codes and standards for hospitals currently. It seems that published standards for these kinds of buildings are still missing the concept of thermal comfort as a part of patients' healing process. Although studying the indoor thermal comfort conditions for hospital occupants looks to be a new matter, but in regarding to the volume of publications presented in this subject during the last few years, it seems to be a new direction in this field which needs more attention. This paper is a literature review on the concept of thermal comfort in hospitals, and it aims to publish a preface for a guideline in this subject.

2. Literatures of thermal comfort in hospitals

Currently there is a considerable volume of literature in thermal comfort studies for hospitals and other healthcare buildings. While some studies are focused on the environmental parameters such as indoor temperature, humidity and air movement, some other investigations have been presented in terms of thermal discomfort and thermal sensation of patients and hospital staff. Some part of literature in this field is focused on the assessing the impact of temperature and humidity variations on infections, bacterial growth, and air borne bacteria.Indoor air quality and hygiene

First part of studies undertaken in hospitals in this field concentrates on the influence of indoor air quality on hygiene of these environments. For example, although, ASHRAE presents chapter seven of its *Applications Handbook* regarding the healthcare facilities, but thermal comfort concept seems to have been ignored within this publication as an important subject. According to chapter seven (healthcare facilities) of the ASHRAE Applications Handbook [1], temperature and humidity can inhibit or increase the growth of bacteria, and activate or deactivate viruses

* Corresponding author. Tel.: +98 841 222 7026; fax: +98 841 222 7026.
E-mail addresses: jamal_kh_k@yahoo.com, j.khodakarami@ilam.ac.ir (J. Khodakarami), nazanin_n_a@yahoo.com, n.nasrollahi@ilam.ac.ir (N. Nasrollahi).

1364-0321/$ – see front matter
doi:10.1016/j.rser.2012.03.054

Table 1
Factors of indoor air quality recommended by ASHRAE [1].

Function space	Pressure relationship to adjacent area	Minimum air changes of outside air per hour	Minimum total air changes per hour	All air exhausted directly to outside	Air recirculated within room units	Relative humidity %	Design temperature, °C
Patient room	[a]	2	6[b]	–	–	30(W), 50(S)	24 ± 1
Newborn nursery suite	[a]	2	6	–	No	30–60	22–26
Labour/delivery/recovery	[a]	2	6[b]	–	–	30(W), 50(S)	24 ± 1
Patient corridor	[a]	2	4	–	–	–	–
General inpatient area not covered in ASHRAE Application handbook [1]	[a]	2	4	–	–	30–60	≤24

[a] Continuous directional control not required.
[b] Total air changes per room may be reduced to four when using supplemental heating and/or cooling systems (radiant heating and cooling, baseboard heating, etc.).

in healthcare buildings. Some bacteria are waterborne and can survive better in a humid environment. Therefore, codes and guidelines for temperature and humidity range criteria in some areas of healthcare buildings are influenced by the measure of infection control as well as comfort [1]. As a variable of thermal comfort conditions, indoor air movement can control or spread the infection in hospitals. Therefore, in such buildings the air-handling systems should provide air movement patterns that minimize the spread of contamination. Table 1 briefly presents some factors of indoor air quality recommended by ASHRAE [1].

In 2006 Murphy has produced Table 2 based on the different guidelines for indoor temperature, humidity and air-change requirements for operation and surgery rooms, and has noted that the surgeon expects a lower room temperature than those stated in these guidelines [2]. The major problem as he has noted in his study is the need for lower air temperature, the high relative humidity and the condensation risk in surgery rooms. In Table 3, based on the loads for calculation of the Space Sensible Heat Ratio (SHR), Murphy has compared three different cooling systems for surgery rooms to try to resolve this problem, which is difficult to be resolved as he noted in the study [2].

Murphy has concluded that using a temperature-only design approach often leads to a system that is unable to meet both requirements, especially when the surgeon lowers the thermostat point [2]. He also has concluded that the output of the system has to be dryer than the other ordinary buildings. As a solution, an additional unit (system of series desiccant wheel) could be added to the ordinary systems to deliver dryer air (at lower dew point) without lowering the coil temperature, so universal chillers can be used. Fig. 1 and Fig. 2 present this solution.

Kameel and Khalil in 2003 in their study on healthcare applications have explained that air temperature and relative humidity can inhibit or promote the growth of bacteria and activate or deactivate viruses, and guidelines specify temperature and humidity range criteria in some hospital areas as a measure for infection control as well as comfort [3]. High temperature may cause an increased out-gassing of toxins from building materials and low temperature can cause occupant discomfort including shivering, inattentiveness and muscular and joint tension. Relative humidity affects occupant comfort both directly and indirectly. Low humidity affects comfort and health in ways such as drying nose, throat, eyes and skin, particularly when the humidity ratio is low and causes a dew point less than 0 °C.

Referring to other studies [4,5], Kameel and Khalil have noted that low humidity can increase susceptibility to respiratory disease as well as affect comfort and it can contribute to irritation [3]. They also have noted that when the dew point temperature is less than 2 °C, then lower relative humidity increases eye discomfort, and higher levels of relative humidity reduce comfort. Thermal sensation is a good indicator of overall thermal comfort and acceptability at lower levels of humidity. However, referred to a study done by Tanabe et al. in high humidity levels, thermal sensation alone is not a reliable predictor [6]. Kameel and Khalil have indicated that an air

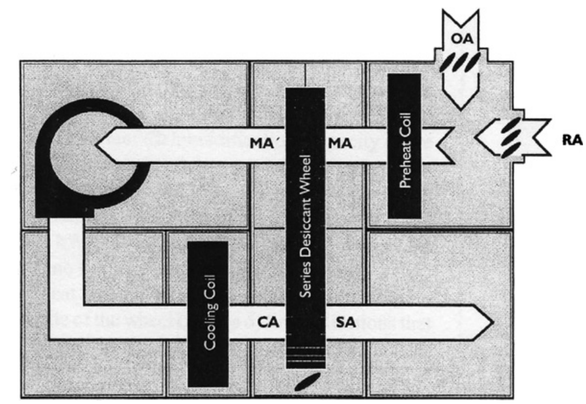


Fig. 1. Air handler with series desiccant wheel [2].

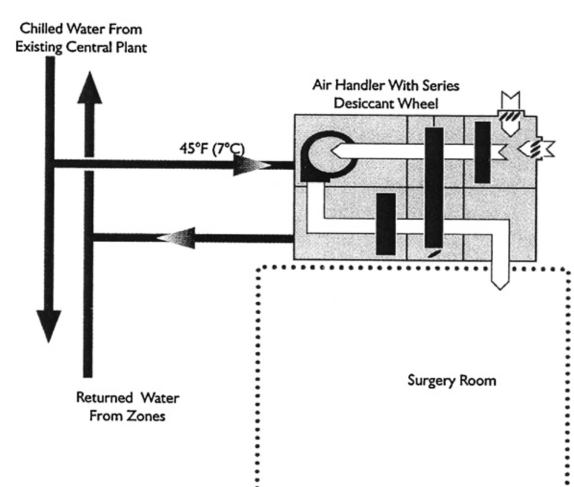


Fig. 2. Air handler with series desiccant wheel served by existing central plant [2].

Table 2
Temperature, humidity, and air-change requirements for surgery rooms [2].

	Dry bulb, °C	Relative humidity %	Room air change	Outdoor air change	Outdoor air %
ASHRAE[a]	20–24	30–60	25	5	20
AIA[b]	20–23	30–60	15	3	20
VA[c]	17–27	45–55	15	15	100

[a] ASHRAE 2003, HVAC Design Manual for Hospitals and Clinics.
[b] American Institute of Architects (AIA) 2001, Guidelines for design and construction of hospital and health care facilities.
[c] United State Department of Veterans Affairs (VA) 2001, HVAC requirements in surgery area, www.va.gov/facmgt.

Table 3
System comparisons at design load [2].

	Space RH	Cooling capacity	Leaving-coil DB	Reheat capacity
Cool and reheat (single cooling coil)	60%	3 tons (10.6 KW)	9 °C	8500 Btu/h (2.5 kW)
Cool and reheat (two cooling coils in series)	60%	3 tons (10.6 KW)		8500 Btu/h (2.5 kW)
Upstream cooling coil		1.8 tons (6.3 KW)	13 °C	
Downstream cooling coil		1.2 tons (4.2 KW)	9 °C	
Series desiccant wheel	55%	2.1 tons (7.4 KW)	11 °C	0 Btu/h (0 kW)

velocity of 0.1 m/s is sufficient in occupied areas of patient rooms [3].

Ninomura et al. in 2001 have explained that to satisfy patient comfort, in patient rooms the total air changes per hour must be a minimum of 6 ACH, but in rooms with supplemental heating and/or cooling this rate may be reduced to 4 ACH [7]. Based on previous research they concluded that the rate of two ACH, which was used in patient rooms before, would create a stuffy room.Different groups means different requirements

Some other researches compare the thermal comfort conditions required by patients in hospitals, with regular occupants of other buildings. Variations in physical and mental conditions of patients compared with normal people are the substance of these kinds of researches. These types of studies almost use the questionnaire and monitoring methods to compare the desired thermal comfort conditions.

In a study in an Italian hospital on a surgical team, based on questionnaire and monitoring methods, Mazzacane et al. in 2007 concluded that it is difficult to realize the thermal conditions recommended by ISPESL guidelines for all staff in the operation room [8,9]. This is due to the different levels of activities during the surgery for different staff, and according to the different kinds of surgery.

In their study in hospital operating rooms, Balaras et al. have noted that thermal comfort as a parameter of indoor air quality in operating rooms affects the working conditions, well-being, safety and health of the medical personnel who work in these environments. They have indicated that the desirable indoor air temperature is 20–24 °C according to international standards, but use of lower or higher temperature is acceptable when patient comfort and/or medical conditions require those conditions. In addition, they noted that higher indoor air temperatures might cause discomfort, as well as, the more favourable growing conditions for bacteria or their migration from and to the patient [10].

Referring to other study, Balaras et al. also reported slightly cool to cold thermal sensation of anaesthetists and nurses, against slightly warm to warm thermal sensation for surgeons, especially when the air temperature is below 21 °C in operating rooms. They have noted that heaver gown requirements used by the surgical team to protect them (i.e. because of AIDS) may require an indoor temperature down to 18 °C or even lower [10,11]. They also referred to Mora et al. have reported a radiant asymmetry ranging from 6 °C to 7 °C over the operating table, and from 10 °C to 12 °C over the floor level (at a height of 1.1 m), because of thermal radiation emitted from surgical lights, regardless of the indoor air temperature [11]. In terms of humidity, Balaras et al. have noted that the humidity level is related to space hygiene and thermal comfort conditions, so it has to be within the accepted levels. Higher levels of humidity cause growth and transfer of bacteria as well as thermal discomfort; lower levels favour blood coagulation, skin drying and thermal discomfort. Referred to international standards they have recommended levels of relative humidity from 30% to 60%, but because of the possible use of inflammable anaesthetic gases and frequent uses of volatile liquids, and therefore in order to prevent the accumulation of static electricity, the relative humidity should sometimes be even higher than 60% in operation rooms [10].

In order to study the patient thermal requirement in hospital environments, a study has been done in Taiwan [12]. The study was based on a survey to compare the ASHRAE standard 55 recommendations for thermal comfort – which is generally for healthy people – with patients. The study used a questionnaire as the research method; it assessed eighty-three medical and surgical wards [13]. The study performed both objective physical measurements and subjective assessments of thermal environment for each ward. They noted that preparing a comfortable thermal environment helps to stabilize the moods of patients and it assists their healing. Comparison of achieved results from patients in hospitals with results achieved from ordinary people in office environments was one of the main purposes in this study. Referred to other studies, this study has used the data achieved from field studies in thermal comfort in offices that were been done by de Dear and Fountain [14] and Chan et al. [15]. Hwang et al. concluded that only 40% of all measured thermal environments were within the ASHRAE recommended comfort zone, and although 47% were above the humidity ranges that recommended by this standard the patients in Taiwan were accepting much higher humidity ranges than that in ASHRAE Standard 55 [12]. The study also revealed that physical strength has a highly significant effect on thermal comfort sensation, whereas the gender, age, and acclimatization have not. The study also concluded that patients expect a warmer indoor environment than neutrality.

In their literature review on staff thermal comfort and patient thermal risks in operating rooms, Melhado et al. in 2006 have shown the importance of investigation this field of study [16]. Regarding to other study by Guyton, Melhado et al. have addressed that outside the normal body temperature, which is about 37 °C (36.1–37.2 °C), a person is considered to be sick, however, he/she can survive at a range of 32–42 °C [17]. Regarding the type of surgery, they have also noted that the thermal comfort variables can change, because of the different conditions of patients, the different activities of staff, the different types and numbers of equipments and lights and so on. Melhado et al. have discussed that although there is a research that shows the link between thermal comfort for staff and their levels of productivity, no studies have been conducted yet in hospitals in this field [16]. They also discussed that, to prevent patient thermal risk, the temperature must not drop below 21 °C referred to Johnston and Hunter [18]. Moreover, referred to other studies done by Leslie and Sessler and Wildt they discussed that a temperature above 23 °C is usually intolerable for the surgical staff, however a temperature between 24 °C and 26 °C is suitable for thermal comfort in general. Using active warming devices can prevent hypothermia more effectively than passive coverings [19,20]. It is preferred to position these devices above the patient for more efficiency referred to Leslie and Sessler [19]. Referring to Mora,

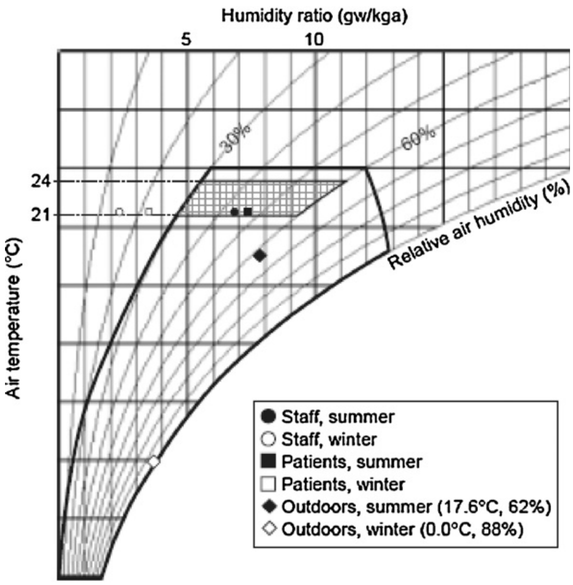


Fig. 3. The psychometric chart for Skoog study [22].

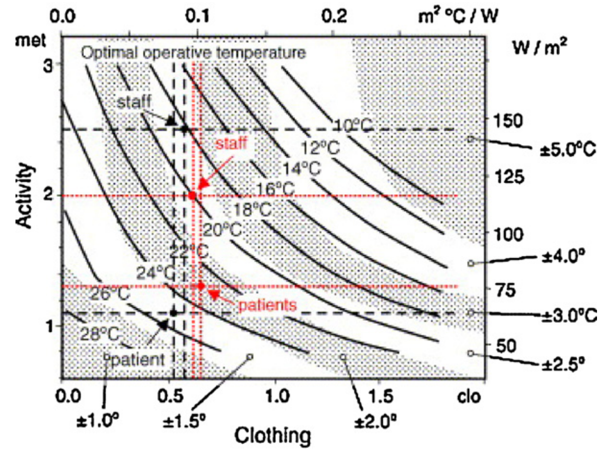


Fig. 4. Optimal operative temperature in summer and winter [22].

Melhado et al. also have noted that the thermal sensation of the surgeon and nurse is hot, while the anaesthesiologist sometimes feels the sensation of cold [21]. To solve this problem they referred to Mora that different thermal zones are required based on different temperature and air velocity for different thermal comfort requirements in operating rooms.

Melhado et al. have concluded that guarding the operating room against infection and achieving good indoor air quality are the main concerns, so there is very little research about staff and patient thermal comfort. They also have concluded that there are important areas, which still need to be focused on including: thermal comfort for staff and its relation with their productivity, using different heating systems to prevent hypothermia in the patient and their influence on staff thermal comfort, improving staff thermal comfort and preventing hypothermia in the patient in same time. As another conclusion, they added that due to different types of activities for staff, different types of patients, different types of lights and occupants and so on, there is a strong need for future research to evaluate staff thermal comfort during different surgeries [16].

In 2006, Skoog has studied the relative humidity in Swedish hospitals during the summer and the winter [22]. The research method used in this study is a combination of objective measurements and questionnaires. The study selected 40 staff and 35 patients in a hospital ward as participants. Skoog has noted from other studies done by Berglund and Reinikainen, that low air humidity affects comfort and health, as reducing the air relative humidity increases respiratory problems [22–24]. Moreover, fewer complaints of dry skin and nose and throat irritation are seen in the humidified part of a building than in a non-humidified part. Skoog has concluded that both indoor air relative humidity and indoor air temperature are low in Swedish hospitals [22]. According to the psychometric chart from her study (Fig. 3), she has shown that low relative humidity, some around 15% were recorded in the case study during the winter. She concluded there is a clear need for humidification in these conditions. The study also compared the results achieved from the objective measurements and the questionnaires. Fig. 4 presents the difference in optimal operative temperature for patients and staff for both summer and winter resulting from their study, from which they concluded that it is wrong to treat the patients and staff as one coherent group of users with the same needs and performances.

However, by analysing the questionnaires Skoog has shown that both patients and staff are satisfied with the indoor air temperature in both summer and winter seasons [22]. This finding contradicts the conclusion drawn from Fig. 4. They discussed that mistakes in assessed activity levels and clothing levels of both types of occupants could generate this difference. As the fact is that the occupants can adapt themselves to the environment through increasing or decreasing of clothing levels; and that the prediction of the activity levels is difficult now that the participants are answering the questionnaires [22]. The combined effects of air and mean radiant temperature can be combined into a single index, the operative temperature, based on study done by Butera [25]. Butera has noted that the operative temperature t_o be defined as the uniform temperature (i.e. equal values of t_{mr} and t_o) of an imaginary enclosure in which man would exchange the same dry heat by radiation and convection as in the actual environment. For thermally moderate environments and for $t_{mr} - t_a < 4\,^{\circ}C$, it may be assumed that $t_o = (t_{mr} + t_a)/2$. The operative temperature can be obtained by measurement using a globe thermometer and a dry bulb thermometer.

Referred to other studies, in another study Skoog et al. in 2005 have noted that due to the risk of infection in hospitals, the indoor air quality has to be better. Skoog et al. added that the patients according to lower levels of activity need a higher operative temperature; medicine taken by patients may affect the metabolism of them; and patients with different thermal requirements may be located in the same wards [26–31].

Hashiguchi et al. in 2005 have studied the indoor environment for occupants in a hospital during the winter [32]. This study was based on objective measurements and subjective questionnaires methodology. The investigation studied 36 patients and 45 staff including nurses and nurses' aides in a hospital in Japan. The survey was undertaken in 20 sickrooms, and at the nurse stations and in the corridors of three floors in 5 stories hospital, in 8 weeks with a 30 min interval in measurements.

Hashiguchi et al. have concluded that the air temperature in the sickrooms was lower than the ranges indicated in standards, but the difference was not significant. However, the average recorded relative humidity (less than 40%) reached levels known to promote the spread of influenza viruses. They also concluded that in contrast with the staff, no direct relation between the thermal comfort sensations for patients and the indoor relative humidity was seen. Both staff and patients have indicated itching skin and thirsting, particularly when the heating system was on. In conclusion, most nurses were aware of their own itchy skin and thirst, they were aware of the ill effects of the heating on patient conditions as well, and finally they did not consider the thermal environments in wards as comfortable working space in this survey during winter [32].

Melhado et al. by using both EnergyPlus and Cterm simulation software have investigated the influence of three layouts of operating rooms on the indoor environment control, on thermal comfort and on energy consumption in sixty cases in five Brazilian cities in different regions [33]. As an introduction, they have noted that the indoor air quality is very important to patients' medical requirements and it could be part of treatment and there is influence of the environment in the infection control. They also noted that due to various types of clothing levels it is important to evaluate the predicted mean vote (PMV) in the operating room. Melhado et al. have concluded that the layout of the operating room has a little influence on thermal comfort [33]. They also concluded that thermal comfort in the operating room was influenced by the type of surgery because the requirements and the heating sources were different, and also concluded that thermal comfort was influenced by the local climate. In all case studies in the research in terms of environment control, the temperature and relative humidity remained within the required ranges so no conditions were favourable for growth of microorganisms.Iranian case study

In a study undertaken by the authors in 2008, the thermal comfort conditions required by occupants in Iranian hospitals were investigated [34–36]. To study the indoor thermal comfort conditions currently provided for hospitals' occupants including patients and staff, 14 patient rooms in four Iranian different hospitals were selected as case studies. A short term monitoring exercise was undertaken in the case studies to enable the more accurate prediction of the indoor thermal comfort conditions being provided for occupants.

Patients that were able to be covered and those that were not able to be covered regarding their medical conditions and hospital staff were selected as the main groups of occupants in this study. A theoretical study was undertaken to determine the desired levels of thermal comfort conditions required by these different groups of occupants.

To reconcile the different thermal comfort conditions requirements, a common range of operative air temperature and different ranges of radiant temperature were found to be needed. The study found that although the monitored rooms were generally within the recommended ranges of the Iranian thermal regulations (M.P.O.) [37]; they were generally out of the thermal comfort zones recommended by ISO7730 [38], ASHRAE 55R and CIBSE [39].

This study also showed that the different groups of hospital occupants had such widely varying thermal comfort requirements that they were difficult to accommodate in one space. The study concluded that theoretically providing different radiant temperatures for the different occupants could reconcile their different thermal comfort requirements in one space for a narrow range of air temperatures [34].Hospital indoor air and the process of healing

There are some others studies that indicate the indoor thermal conditions of hospitals as a part of the healing process of patients. Wagner et al. in 2006 referred to other studies such as Fossum et al. and Wagner, have noted that memories of thermal comfort or discomfort during surgery have an effect on a patient's overall satisfaction with surgical care. Also referred to other studies they added that warming a patient preoperatively is more effectively accomplished by using an active warming method such as a convective method including warmed air. In addition, they have defined cold as an uncomfortable sensation that can increase restlessness, aggravate pain, and decrease overall patient satisfaction [40–44]. Gagge and Nishi in 1977 have noted that the combined effect of external thermal environment and internal metabolic heat production constitutes thermal stress on the body [45].

Referred to a study done by Parsons in 2002 thermal sensation is related to how people "feel" and is therefore a sensory experience and a psychological phenomenon [46]. Many studies have correlated the physical conditions and the physiological response with the thermal sensation to provide models for predicting the thermal sensation of groups of individuals. It is important to recognize that thermal sensation is how the person feels, not how the environment may be described. Although referred to Fanger 1970, human thermal environments are defined by six basic parameters, but Parsons indicated that it is the integration of the parameters that determines the thermal state of the body, and thermal sensation is determined by the "thermal state" of the body and not an environmental component [46,47]. However, the authors confirm that thermal sensation of occupants can be a good indicator in terms of their thermal requirements, but in terms of patients who are not in usual physical or mental conditions; their thermal sensations might be false. Using medicines, losing the sensory receptors in some patients and other factors can cause unrealistic thermal sensations.

3. Discussion

It is good to point out that guarding the patient against infection and providing a good indoor air quality are the two main concerns in hospitals while there is very little research in thermal comfort for patient and staff in the body of literatures. However, good indoor air quality could be part of treatment and it affects the infection control, but preparing a comfortable thermal environment helps to stabilize the emotional moods of patients and it assists with their healing process. In addition, it is point of discussion that memories of thermal comfort or discomfort during surgery have an effect on a patient's overall satisfaction with surgical care. The combined effect of external thermal environment and internal metabolic heat production constitutes thermal stress on the body.

Patients expect a warmer indoor environment than neutrality. Medicine taken by patients may affect their metabolism. Cold is an uncomfortable sensation that can increase restlessness, aggravate pain, shivering, inattentiveness, muscular and joint tension, and decrease overall patient satisfaction. Using active warming devices can prevent hypothermia more effectively than passive coverings. It is preferred to position these devices above the patient for more efficiency.

To prevent the patient thermal risk in operating rooms the temperature must not drop below 21 °C and a temperature above 23 °C is usually intolerable for the surgical staff; however, a temperature between 24 °C and 26 °C is suitable for thermal comfort in general. Desirable indoor air temperature is 20–24 °C according to international standards, but use of lower or higher temperature is acceptable when patient comfort and/or medical conditions require those conditions.

From the review, we can say that thermal comfort as a parameter of indoor air quality in hospital affects the working conditions, well-being, safety and health of the medical personnel who work in these environments.

Using a temperature-only design approach often leads to a system that is unable to meet both patient and staff requirements, especially when staff lowers the thermostat point. As a solution, an additional unit could be added to the ordinary systems to deliver dryer air without lowering the coil temperature.

Thermal comfort variables can change, based on different conditions of patients, the different activities of staff, the different types and numbers of equipments. To solve this problem the best-recommended option is to prepare different thermal zones based on different temperature and air velocity for different thermal comfort requirements.

Higher levels of humidity would cause the growth and transfer of bacteria as well as thermal discomfort; lower levels of humidity favour blood coagulation, skin and nose drying, throat irritation, respiratory problems and thermal discomfort. International standards have recommended levels of relative humidity from 30% to

60%, but because of possibility uses of in-flammable anaesthetic gases and frequently uses of volatile liquids, in order to prevent the accumulation of static electricity, the relative humidity should be in higher levels even more than 60% in operation rooms.

Indoor air movement as a variable of thermal comfort conditions can control or spread the infection in hospitals. Air velocity of 0.1 m/s is sufficient in occupied areas of patient rooms. To satisfy patients' comfort, within patients' rooms the total air changes per hour must be 6 ACH, but in rooms with supplemental heating and/or cooling this rate may be reduced to 4 ACH.

4. Conclusion and recommendations

All the studies in this literature review were undertaken in just a single hospital for each case study, and generally for one type of occupant. Making general conclusions based on the results achieved from just one case study is considered insufficient by the author where the literature reviewed of this study would be considered to be lacking.

In the literature review, whenever the studies referenced tried to discuss the thermal conditions for *different groups of occupants* in one room, the studies ended up simply presenting comparisons of thermal comfort satisfaction based on the subjective studies. No study in the literature tried to reconcile the different thermal comfort requirements of different types of occupants who compulsorily must stay in one room. Therefore, it looks to be necessary to investigate the different thermal conditions required by different groups of occupants in hospitals to reconcile their different requirements in this concept. To reconcile the differences in the required thermal comfort conditions the study recommends testing the possibility of using different ranges of local radiant temperature in one room via a suitable mechanical system.

Although different researches are undertaken on thermal comfort for patients in hospitals, it is also necessary to study the effects of thermal comfort conditions on the quality and the quantity of healing for patients in hospitals. There are also original researches that show the link between thermal comfort for staff and their levels of productivity, but no studies have been produced individually in hospitals in this field. Therefore, this study recommends researches for coverage and methods individually for this subject. The authors also recommend research in terms of cooling and heating delivery systems for patients with low levels of immune system protection such as HIV patients, burned patients, etc. However, there is research that shows the link between thermal comfort for staff and their levels of productivity, but no study have been produced in hospitals in this field. There are important areas, which still need to be focused on including thermal comfort for staff and its relation with their productivity, using different heating system to prevent hypothermia in the patient and to improve the thermal comfort for hospital staff simultaneously.

Finally, the authors believe that the interaction between people, systems and architectural design in hospitals is a field in which require further work needed to improve the knowledge of how to design buildings and systems to reconcile many conflicting factors for the people occupying these buildings.

References

[1] ASHRAE. Chapter seven: healthcare facilities. In: HVAC Applications handbook. ASHRAE; 2003.
[2] Murphy J. Temperature and humidity control in surgery rooms. ASHRAE Journal 2006;48:18–25. Health-Care HVAC.
[3] Kameel R, Khalil E. Thermal comfort VS air quality in air-conditioned healthcare applications. In: 36th AIAA thermophysics conference 2003. 2003.
[4] Berglund LG. Comfort and humidity. ASHRAE Journal 1998:35–40. August.
[5] Liviana JE, Rohles FH, Bullock PE. Humidity comfort and contact lenses. ASHRAE Transactions 1988;94(1):3–11.
[6] Tanabe S, Kimura K, Hara T. Thermal comfort requirement during summer season in Japan. ASHRAE Transactions 1987;93(1):564–77.
[7] Ninomura PE, Bartley J. New ventilation guidelines for health-care facilities. ASHRAE Journal 2001:29–33. Ventilation, June.
[8] Mazzacane S, Giaconia C, Costanzo S, Cusumano A. A survey on thermal conditions experienced by a surgical team. Indoor and Built Environment 2007;16(2):99–109.
[9] ISPESL (Istituto Superiore Prevenzione e Sicurezza sul Lavoro) Guidelines: Dipartimento di Igiene del Lavoro Linee guida per la definizione degli standard si sicurezza e di igiene ambientale dei reparti opratori: [Department of Occupational Hygiene, Guidelines defining satety standards and environmental hygiene for surgical departments], 1999.
[10] Balaras CA, Dascalaki E, Gaglia A. HVAC and indoor thermal comfort conditions in hospital operating rooms. Energy and Building 2007;39:454–70.
[11] Mora R, English MJM, Athienitis AK. Assessment of thermal comfort during surgical operations. ASHRAE Transactions 2001;107(part 1):52–62.
[12] Hwang RL, Lin TP, Cheng MJ, Chien JH. Patient thermal comfort requirement for hospital environments in Taiwan. Building and Environment 2007;42: 2980–7.
[13] ASHRAE Standard 55R. Thermal environmental conditions for human occupancy. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc; 2004.
[14] de Dear RJ, Fountain ME. Field experiments on occupant comfort and office thermal environments in a hot-humid climate. ASHRAE Transactions 1994;100(part 2):457–75.
[15] Chan WT, Burnett J, de Dear RJ, Ng CH. A large-scale survey of thermal comfort in office premises in Hong Kong. ASHRAE Transactions 1998;104(part 1B):1172–80.
[16] Melhado M, Hensen JLM, Loomans M. Literature review of staff thermal comfort and patient thermal risks in operating rooms. In: Proceedings of the 8th International healthy buildings conference. 2006. pp. 11–14.
[17] Guyton AC. Fisiologia humana. Rio de Janeiro: Guanabara KOOgan; 1998.
[18] Johnston IDA, Hunter AR. The design and utilization of operating theatres. The Royal College of Surgeons of England; 1984.
[19] Leslie K, Sessler DI. Perioperative hypothermia in the high-risk surgical patient. Best Practice & Research: Clinical Anaesthesiology 2003;17(4):485–98.
[20] Wildt M. Pressure hierarchy and indoor climate of hospital rooms. In: Maroni M, et al., editors. Ventilation and indoor air quality in hospitals. Kluwer Academic Publishers; 1996. pp. 219–225.
[21] Mora R. Assessment of thermal comfort during surgical operations. In: ASHRAE winter meeting program. 2001.
[22] Skoog J. Relative air humidity in hospital wards – user perception and technical consequences. Indoor and Built Environment 2006;15(1):93–7.
[23] Berglund LG. Comfort and humidity. ASHRAE Journal 2002:35–41. July.
[24] Reinikainen LM. The effect of air humidification on different symptoms in office workers – an epidemiological study. Environment International 1991;17(4):243–50.
[25] Butera FM. Chapter 3 – Principles of thermal comfort. Renewable and Sustainable Energy Reviews 1998;2:39–66.
[26] Montz WE. Indoor air quality in hospitals. www.stachybotrys.com/iaqhospitals.htm [accessed 19.06.03].
[27] R1, Classified Indoor Climate Systems – Guiding principles and Specifications (in Swedish), VVS Tekniska Föreningen/Förlags AB, Ödeshög, Sweden, 2000.
[28] Parsons KC. The effects of gender, acclimation state, the opportunity to adjust clothing and physical disability on requirements for thermal comfort. Energy and Buildings 2002;34(6):593–9.
[29] Buskirk ER, Loomis JL. Aspects of indoor environments: tolerable vs. comfortable thermal environments. In: Thermal analysis – human comfort – indoor environments. Gaithersburg, MD, United States of America: U.S. Department of Commerce/National Bureau of Standards; 1977.
[30] Wang X, Peterson F. To stay in warm and damped environment – how you perceive the heat. Energi & Miljö 1995;66(7–8):46–8.
[31] Skoog J, Fransson N, Jagemar L. Thermal environment in Swedish hospitals summer and winter measurements. Energy and Building 2005;37:872–7.
[32] Hashiguchi N, Hirakawa M, Tochihara Y, Kaji Y, Karaki C. Thermal environment and subjective responses of patients and staff in a hospital during the winter. Journal of Physiological Anthropology and Applied Human Science 2005;24(1):111–5.
[33] Melhado MA, Beyer PO, Hensen JM, Siqueira LFG. The thermal comfort, the indoor environment control, and the energy consumption in three types of operating rooms. In: Building simulation, 9th International IBPSA Conference. 2005.
[34] Khodakarami J, Knight I. Required and current thermal conditions for occupants in Iranian hospitals. HVAC & Research Journal 2008;14(No 2):175–94.
[35] Khodakarami J, Knight I, Nasrollahi N. Reducing the demands of heating and cooling in Iranian hospitals. Renewable Energy 2009;34:1162–8.
[36] Khodakarami J. Achieving thermal comfort in Iranian hospitals. VDM Verlag; 2009. ISBN 978-3639182927.
[37] M.P.O. (Management Planning Organization). Health Building design1/design guide for architectural planning and design of medical surgical care unites. Islamic republic of Iran: M.P.O.; 2004.
[38] ISO, International standard 7730. Moderate thermal environments – determination of PMV and PPD indices and specification of the conditions of thermal comfort. Geneva: International standards organization; 2005.
[39] CIBSE. Environmental design, CIBSE Guide A. London: the chartered Institution of Building Services Engineers; 1999.

[40] Wagner D, Byrne M, Kolcaba K. Effects of comfort warming on preoperative patients. ARON Journal 2006;84(3):427–47.
[41] Fossum S, Hays J, Henson MM. A comparison study on the effects of prewarming patients in the outpatient surgery setting. Journal of PeriAnesthesia Nursing 2001;17:102–14.
[42] Wagner VD. Impact of perioperative temperature management on patient safety. Surgical Services Management 2003;9(4):38–43.
[43] Sessler DI, Schroeder M, Merrifield B, Matsukawa T, Cheng C. Optimal duration and temperature of pre-warming. Anesthesiology 1995;82(3):674–81.
[44] D'Angelo Vanni SM, Braz JRC, Módolo NSP, Amorim RB, Rodrigues GR. Preoperative combined with intraoperative skin–surface warming avoids hypothermia caused by general anesthesia and surgery. Journal of Clinical Anesthesia 2003;15(2):119–25.
[45] Gagge AP, Nishi Y. Heat exchange between human skin surface and thermal environment. Handbook of Physiology 1977:69–92.
[46] Parsons KC. Human thermal environments – the effects of hot, moderate, and cold environments on human health. In: Comfort and performance. Taylor & Francis; 2003.
[47] Fanger PO. Thermal comfort – analysis and application in environmental engineering. Copenhagen: Danish Technical Press; 1970.